

## IMAGE PROCESSING APPARATUS

[0001] This application is based on Application No. 2001-1225 filed in Japan, contents of which is hereby incorporated by reference.

### BACKGROUND OF THE INVENTION

#### 1. FIELD OF THE INVENTION

[0002] The present invention relates to an image processing apparatus that discriminates attributes of each pixel and changes processing methods in accordance with a discrimination result. More particularly, the present invention relates to an image processing apparatus capable of precisely discriminating a color halftone dot region from other types of image regions.

#### 2. DESCRIPTION OF RELATED ART

[0003] In a digital copying machine or the like for reading an image by using a CCD sensor and decomposing the read image into image pixels, thereby carrying out image processing, an optimal image processing method differs depending on a character image, a photography image, and a halftone dot image. Because of this, in such a digital copying machine or the like, the image attribute is discriminated, whereby the image processing method is changed according to the discrimination result. Accordingly, precision is required when discriminating image attributes. Generally, an edge enhancement

processing is applied to an image discriminated as a character image and a smoothing processing is applied to an image discriminated as a photographic image or a halftone dot image. Furthermore, It has been well-known that in case that an edge enhancement processing is to be applied to a character region in a halftone dot image, the edge enhancement processing is applied if halftone dots in the halftone dot image are color whereas a smoothing processing is applied if the halftone dots are black.

[0004] With the following reasons, an edge enhancement processing is applied to a character region in a halftone dot image in case that the halftone dots are color. That is, as shown in FIG. 24A, if black halftone dots are erroneously discriminated as a black character, proportional difference between black(K) and cyan(C), magenta(M), yellow(Y) becomes larger. Thereby, hue of a reproduction image is different from that of an original image and the reproduction image is likely to have image noises. On the other hand, as shown in FIG. 24B, even if color halftone dots are erroneously discriminated as a color character, proportion difference between black(K) and cyan(C), magenta(M), yellow(Y) does not change. Therefore, hue of a reproduction image does not differ compared with that of an original image. This is because image noises do not stand out in the reproduction image. Accordingly, discrimination of a character region in a black halftone dot region is not carried out but discrimination of a

character region in a color halftone dot region is carried out. Therefore, edge enhancement processing is applied to a character region if the character region is in a color halftone dot region, thereby reproducing image with high quality.

**[0005]** However, in the above described conventional image processing apparatus, there has been a problem that if a color halftone dot image contains a black character in there, its color halftone dot region can hardly be discriminated as so precisely. That is, there has been a fear that color halftone dot regions around boundaries of a black character can hardly be discriminated precisely. This is because the number of color pixels existing in a predetermined region including a target pixel decreases around the boundary of the color halftone dot region and the black character region, whereby a count value of the color pixels approximates to a discrimination value. From this reason, there has been the fear that a color halftone dot region is erroneously discriminated as a black halftone dot region. If the color halftone dot region is erroneously discriminated as a black halftone dot region, a smoothing processing is also applied to a character region in the color halftone dot region. Therefore, even if it is a character in a color halftone dot image, an image of the character is not always reproduced precisely.

## SUMMARY OF THE INVENTION

[0006] The present invention has been made in order to solve the foregoing problem. It is an object of the present invention to provide an image processing apparatus for precisely discriminating a color halftone dot region regardless of color of a character in the color halftone dot image, thereby making it possible to reproduce the character image in the color halftone dot image with high precision.

[0007] According to one aspect of the present invention, there is provided an image processing apparatus, comprising: a first discrimination unit that discriminates whether or not a target pixel belongs to a halftone dot region; a second discrimination unit that discriminates whether or not the target pixel belongs to a color region; a color region extending section that recognizes an extended region as an extended color region on condition that the extended region is formed by pixels that, the second discrimination unit has discriminated, belong to a color region; and a color halftone dot region discriminating unit that discriminates a region as a color halftone dot region on condition that the region is recognized as an extended color region by the color region extending section and is formed by pixels that, the first discrimination unit has discriminated, belong to a halftone dot region.

[0008] In this image processing apparatus, firstly, an attribute of a target pixel is determined. That is, the

first discrimination unit discriminates whether or not the target pixel belongs to a halftone dot region. Furthermore, the second discrimination unit discriminates whether or not the target pixel belongs to a color region. Next, the color region extending section recognizes an extended region as an extended color region on condition that the extended region is formed by pixels that, the second discrimination unit has discriminated, belong to a color region.

**[0009]** The color region extending section is provided and a color region is extended so as to avoid erroneous discrimination of a color region. That is, the above items prevent a situation such that, in case that a black character exists in a color region, the number of color pixels existing in a predetermined region including a target pixel decreases around the boundary of the color halftone dot region and the black character region and a count value of the color pixels approximates to a discrimination value. Thereby, the color region is discriminated precisely even if a black character exists in a color region.

**[0010]** Subsequently, a region that meets the following two conditions is finally discriminated as a color halftone dot region: (1) a region that the color halftone dot region discrimination unit has discriminated as an extended color region recognized by the color region extending section; and (2) a region formed by pixels that, the first discrimination unit has discriminated, belong to a halftone dot region. Since a color region is thus precisely

discriminated, a color halftone dot region is precisely discriminated at the color halftone dot region discrimination unit. That is, even if a black character exists in a color halftone dot region, the color halftone dot region is precisely discriminated as so at the color halftone dot region discrimination unit.

[0011] As has been described above, according to the image processing apparatus of the present invention, a color halftone dot region can be precisely discriminated regardless of color of character in the color halftone dot region. Therefore, a character in a color halftone dot region can be reproduced with high precision because an edge enhancement processing can surely be applied to a character region in the color halftone dot region.

[0012] According to another aspect of the present invention, there is provided an image processing apparatus, comprising: a first discrimination unit that discriminates whether or not each pixel belongs to a halftone dot region based on image data; a second discrimination unit that discriminates whether or not each pixel belongs to a color region based on image data; a color region extending section that extends a color region formed by pixels that, the second discrimination unit has discriminated, belong to the color region; a color halftone dot region discrimination unit that discriminates pixels that belong to a color halftone dot region on condition that the pixels are included in a color region extended by the color region extending section,

discriminated by the first discrimination unit such that the pixels belong to a halftone dot region; and an image process unit that corrects image data based on a discrimination result obtained by the color halftone dot region discrimination unit.

**[0013]** In this image processing apparatus as well, image processing similar to the afore-mentioned image processing apparatus is carried out. That is, firstly, the first discrimination unit discriminates a pixel that belongs to a halftone dot region and the second discrimination unit discriminates a pixel that belongs to a color region. Next, the color region extending section extends a color region formed by pixels that, the second discrimination unit has discriminated, belong to a color region. Then, the color halftone dot region discriminating unit discriminates pixels that belong to a color halftone dot region on condition that the pixels are included in a color region extended by the color region extending section, discriminated by the first discrimination unit such that the pixels belong to a halftone dot region. Finally, the image process unit corrects image data based on a discrimination result obtained by the color halftone dot region discrimination unit. In the image process unit, edge enhancement processing is surely applied to the character region in the color halftone dot region so as to correct image data. Accordingly, a character in a color halftone dot region can be reproduced with high precision.

[0014] According to still another aspect of the present invention, there is provided an image processing method comprising: a step 1 of discriminating whether or not each pixel of image data belongs to a halftone dot region as well as whether or not each pixel of image data belongs to a color region; a step 2 of extending a color region formed by pixels that, the step 1 has determined, belong to a color region; a step 3 of discriminating pixels that belong to a color halftone dot region on condition that the pixels are included in a color region extended by the step 2, and discriminated by the step 1 such that the pixels belong to a halftone dot region; and a step 4 of correcting image data based on a discrimination obtained by the step 3.

[0015] In this image processing method, firstly, the step 1 discriminates whether or not each pixel of image data belongs to a halftone dot region as well as whether or not each pixel of image data belong to a color region. Next, the step 2 extends a color region formed by pixels that, the step 1 has determined, belong to the color region. Then, the step 3 discriminates pixels that belong to a color halftone dot region on condition that the pixels are included in a color region extended by the step 2, and discriminated by the step 1 such that the pixels belong to a halftone dot region. Finally, the step 4 corrects image date based on a discrimination result obtained by the step 3.

[0016] As has been described above, according to the data processing method of the present invention, a pixel that

meets the following two conditions is discriminated as a pixel that belongs to a color halftone dot region: (1) the pixel is included in an extended color region; and (2) the pixel belongs to a halftone dot region. Then, image data correction is carried out based on the discrimination result. Therefore, even if the number of color pixels existing in a predetermined region including a target pixel decreases around the boundary of the color halftone dot region and the black character region and a count value of the color pixels approximates to a discrimination value, the color region is discriminated as so precisely. Since a color region can be discriminated precisely, a color halftone dot region can be discriminated precisely, as well.

Accordingly, with the inventive image processing method, a color halftone dot region can be discriminated as so precisely regardless of color of a character in the color halftone dot image, thereby making it possible to reproduce the character image in the color halftone dot image with high precision.

**[0017]** Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF DRAWINGS

[0018] For a better understanding of the present invention, reference is made to the following detailed description of the invention, just in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram depicting a schematic construction of a color image processing apparatus according to one embodiment of the present invention;

FIG. 2 is a block diagram depicting a schematic construction of a region discriminating portion shown in FIG. 1;

FIG. 3 is a block diagram depicting a schematic construction of a color signal generating section in Fig. 2;

FIG. 4 is a block diagram depicting a schematic construction of a various-edge signal generating sections shown in FIG. 2;

FIG. 5 is a view showing a primary differential filter (main scanning direction);

FIG. 6 is a view showing a primary differential filter (sub-scanning direction);

FIG. 7 is a view showing a secondary differential filter (+ type);

FIG. 8 is a view showing a secondary differential filter (x type);

FIG. 9 is a view showing an external / internal edge discriminating filter;

FIG. 10 is a view showing an isolation point detection

filter;

FIG. 11 is a view illustrating a discrimination method in the external / internal edge discriminating section in FIG. 4;

FIG. 12 is a block diagram depicting a schematic construction of a halftone dot / color region signal generating section in FIG. 2;

FIG. 13 is a view illustrating the processing content at a halftone dot region extension processing section shown in FIG. 12;

FIG. 14 is a block diagram depicting a schematic construction of a halftone dot internal character region signal generating section shown in FIG. 2;

FIG. 15 is a view showing a part of the contents of a table at an MTF control signal generating section shown in FIG. 2;

FIG. 16 is a block diagram depicting a schematic construction of an MTF correcting section shown in FIG. 1;

FIG. 17 is a view showing a -45 degree differential filter;

FIG. 18 is a view showing a 0 degree differential filter;

FIG. 19 is a view showing a +45 degree differential filter;

FIG. 20 is a view showing a +90 degree differential filter;

FIG. 21 is a view showing a smoothing filter;

FIG. 22 is a view showing a min filter;

FIG. 23 is a view specifically illustrating a method of discriminating a character region in a halftone dot image;

FIG. 24 is a view illustrating why whole smoothing processing is applied to a black halftone dot region; and

FIG. 25 is a view showing effects obtained by extending a color region.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

**[0019]** Reference will now be made in detail to the presently preferred embodiments of the invention as illustrated in the accompanying drawings, in which like reference numerals designate like or corresponding parts.

**[0020]** Hereinafter, the best mode embodying an image processing apparatus according to the present invention will be described in detail with reference to the accompanying drawings. According to the present embodiment, the present invention is applied to a color image processing apparatus. In the present embodiment, a halftone dot internal character denotes a character image drawn in a halftone dot image expressed by halftone dots, a background of which is expressed by halftone dots. In addition, a halftone dot internal character region denotes a region of a character image drawn in the halftone dot image.

**[0021]** A schematic construction of a color image processing apparatus according to the present embodiment is shown in FIG. 1. This color image processing apparatus

comprises: a CCD sensor 11; an image composing section 12; an A/D converting section 13; a shading correcting section 14; an interline correcting section 15 that carries out correction between lines; a color aberration correcting section 16 that corrects a color aberration of each color; a magnification change / movement processing section 17; a color converting section 18; a color correcting section 19; a region discriminating section 20; an MTF correcting section 21; and a printer interface (I/F) 22.

**[0022]** The CCD sensor 11 receives reflection light obtained by scanning a document with a scanner, converts the obtained light in a photoelectric manner, and acquires an analog RGB signal. The image composing section 12 composes an odd (odd numbered component) and even (even numbered component) with each other relevant to a respective one of the analog RGB signals acquired by the CCD sensor 11. The A/D converting section 13 converts the analog RGB signal composed by the image composing section 12 into a digital signal. The image composing section 12 and A/D converting section 13 are provided for a respective one of the RGB signals.

**[0023]** The shading correcting section 14 eliminates non-uniformity of light quantity in the main scanning direction on an image. Specifically, prior to a document reading operation, the reflection light from a white plate for shading correction is received by the CCD sensor 11, the obtained analog data is converted into digital data,

and the digital data is stored in a memory. During document reading, the document read data is corrected while the digital data stored in the memory is defined as a reference value.

**[0024]** The magnification change / movement processing section 17 controls memory write and readout operations, thereby carrying out enlargement / reduction processing in the main scanning direction of an image and image movement processing. The color converting section 18 converts a current color into a specified display color system, wherein Lab data is produced based on the RGB signal. Then, the Lab data produced at the color converting section 18 is inputted to the color correcting section 19 and region discriminating section 20. The color correcting section 19 produces a recording density signal CMYK which can be recorded by a desired color considering spectroscopy characteristics of an actually used four-color toner and a recording process based on the Lab data.

**[0025]** The region discriminating section 20 discriminates an image attribute for each pixel, generates signals that correspond to each attribute so as to finally generate a control signal (CMPX, KMPX) for an MTF correcting section 21 based on these signals. This region discriminating section 20 comprises a color signal generating section 30, a various-edge signal generating sections 31, a halftone dot / color region signal generating section 32, a halftone dot internal character region signal

generating section 33, and an MTF control signal generating section 34 as shown in Fig.2.

**[0026]** The color signal generating section 30 generates a color signal (COLOR) and a black region signal (\_BLACK) based on the Lab data generated at the color converting section 18. The color signal generating section 30 is composed of a converting section 35, a color discriminating threshold table 36, and a black discriminating threshold table 37, and two comparators 38 and 39, as shown in FIG. 3.

**[0027]** The converting section 35 generates saturation data (W7-0) in accordance with a conversion formula ( $\sqrt{a^2 + b^2}$ ) using data (a7-0, b7-0) generated at the color converting section 18. The color discrimination threshold table 36 generates a threshold for generating a color signal (COLOR) based on the lightness data (L7-0). In addition, the black discrimination threshold table 37 generates a threshold for generating a black region signal (\_BLACK) based on lightness data (L7-0). The thresholds for generating the color signal (COLOR) and black region signal (\_BLACK) are generated based on the lightness data (L7-0) because the saturation quantity non-linearly depends on the lightness.

**[0028]** With such a construction, the color signal generating section 30 compares the saturation data (W7-0) with the threshold generated by the color discrimination threshold table 36 in a comparator 38, thereby generating

a color signal (COLOR). In addition, in a comparator 39, this section compares the saturation data (W7-0) with the threshold generated by the black discrimination threshold table 37, thereby generating a black region signal (\_BLACK).

**[0029]** Turning to FIG. 2, the various-edge signal generating section 31 generates a halftone dot discrimination isolation point signal (WAMI, KAMI), a halftone dot internal character region detection edge signal (\_EDGL), a halftone dot internal character region detection internal edge signal (\_INEDG), and a character edge region signal (\_EDG) based on the lightness data (L7-0). Then, in order to generate these signals, the various-edge signal generating section 31 includes: a matrix generating section 41; a characteristic quantity sampling filter section 42; two selectors 43 and 44; four comparators 45 to 48; an external / internal edge discriminating section 49; two OR circuits 50 and 51, as shown in FIG. 4.

**[0030]** The matrix generating section 41 generates matrix data of 5x5 pixel size from input image data. Then, filter processing caused by the characteristic quantity sampling filter 42 is applied to matrix data generated at the matrix generating section 41. The characteristic quantity sampling filter section 42 comprises: primary differential filters (main scanning direction and sub-scanning direction) 52 and 53; secondary differential filters (+ type and x type) 54 and 55; an external / internal edge discriminating filter 56; and an isolation point detecting

filter 57. In the present embodiment, the primary differential filter 52 in the main scanning direction shown in FIG. 5 is used, and the primary differential filter 53 in the sub-scanning direction shown in FIG. 6 is used. In addition, the + type secondary differential filter 54 shown in FIG. 7 is used, and the x type secondary differential filter 55 shown in FIG. 8 is used. Further, the external / internal edge discriminating filter 56 shown in FIG. 9 is used.

**[0031]** Furthermore, the isolation point detecting filter 57 shown in FIG. 10 is used. This isolation point detecting filter 57 includes a white isolation point detecting filter 57a and a black isolation point detecting filter 57b. In the case where the lightness value of a target pixel V33 is greater than that of the peripheral eight pixels, and is greater than the average lightness value of two pixels in eight directions, the white isolation point detecting filter 57a detects that the halftone dot discrimination isolation point signal (WAMI) is "H" active.

**[0032]** Namely, in the case where the lightness value of the target pixel V33 meets the following condition, it is discriminated that the target pixel V33 is a white isolation point (WAMI = "H"). In this case, all of the conditions indicated below must be satisfied:

$V33 > \text{MAX} (V22, V23, V24, V32, V34, V42, V43, V44); \text{ and}$   
 $V33 > (V11 + V22) / 2 + \text{OFFSET}; \text{ and}$   
 $V33 > (V13 + V23) / 2 + \text{OFFSET}; \text{ and}$

V33 > (V15 + V24) / 2 + OFFSET; and  
V33 > (V31 + V32) / 2 + OFFSET; and  
V33 > (V35 + V34) / 2 + OFFSET; and  
V33 > (V51 + V42) / 2 + OFFSET; and  
V33 > (V53 + V43) / 2 + OFFSET; and  
V33 > (V55 + V44) / 2 + OFFSET.

[0033] In addition, in the case where the lightness value of the target pixel V33 is smaller than that of the periphery eight pixels, and is smaller than the average lightness value of two pixels in eight directions, the black isolation point detecting filter 57b detects that the halftone dot discrimination isolation point signal (KAMI) is "H" active.

[0034] Namely, in the case where the lightness value of the target pixel V33 meets the following condition, it is discriminated that the target pixel V33 is a black isolation point (KAMI = "H"). In this case, all of the conditions indicated below must be satisfied:

V33 < MIN (V22, V23, V24, V32, V34, V42, V43, V44); and  
V33 + OFFSET < (V11 + V22) / 2; and  
V33 + OFFSET < (V13 + V23) / 2; and  
V33 + OFFSET < (V15 + V24) / 2; and  
V33 + OFFSET < (V31 + V32) / 2; and  
V33 + OFFSET < (V35 + V34) / 2; and  
V33 + OFFSET < (V51 + V42) / 2; and  
V33 + OFFSET < (V53 + V43) / 2; and  
V33 + OFFSET < (V55 + V44) / 2.

OFFSET is a threshold for discriminating an isolation point.

[0035] Turning to FIG. 4, an output from the primary differential filter 52 in the main scanning direction is inputted to terminal A of the selector 43, and an output from the primary differential filter 53 in the sub-scanning direction is outputted to terminal B of the selector 43. In addition, an output from the + type secondary differential filter 54 is inputted to terminal A of the selector 44, and an output from the x type secondary differential filter 55 is inputted to terminal B of the selector 44. In the selectors 43 and 44 each, a greater one of the values inputted to terminals A and B is selected and outputted.

[0036] In addition, an output (EDG07-00) from the selector 43 is inputted to terminal P of the comparator 45, and an edge reference value (EDGREF07-00) is inputted to terminal Q of the comparator 45. Similarly, an output (EDG07-00) from the selector 43 is inputted to terminal P of the comparator 46, an edge reference value (EDGREF17-10) is inputted to terminal Q of the comparator 46. On the other hand, an output (EDG17-10) from the selector 44 is inputted to terminal P of the comparator 47, and an edge reference value (EDGREF27-20) is inputted to terminal Q of the comparator 47. Similarly, an output (EDG17-10) from the selector 44 is inputted to terminal P of the comparator 48, and an edge reference value (EDGREF37-30) is inputted to terminal Q of the comparator 48.

[0037] An output of the comparator 45 and that of the comparator 47 are inputted to an OR circuit 50. In addition,

an output of the comparator 46 and that of the comparator 48 are inputted to an OR circuit 51. With the above construction, in the OR circuit 50, in the case where any of the following conditions (1) and (2) is met, a character edge region signal (\_EDG) is set to "L" active. The conditions include: (1) a case in which the maximum value of values filtered by the primary filter 52 in the main scanning direction and the primary filter 53 in the sub-scanning direction is greater than an edge reference value (EDGREF07-00); and (2) a case in which the maximum value of values filtered by the + type secondary differential filter 54 and x type secondary differential filter 55 is greater than an edge reference value (EDGREF27-20).

**[0038]** Similarly, in the OR circuit 51, in the case where any of the following conditions (3) and (4) is met, a halftone dot internal character region detection edge signal (\_EDGL) is set to "L" active. The conditions include: (3) a case in which the maximum value of values filtered by the primary filter 52 in the main scanning direction and the primary filter 53 in the sub-scanning direction is greater than an edge reference value (EDGREF17-10); and (4) a case in which the maximum value of values filtered by the + type secondary differential filter 54 and x type secondary differential filter 55 is greater than an edge reference value (EDGREF37-30).

**[0039]** The value filtered by the external / internal edge discriminating filter 56 and the discrimination reference

value (INOUT7-0) are inputted to the external / internal edge discriminating section 49. In the external / internal edge discriminating section 49, the external / internal edge is discriminated as shown in FIG. 11. That is, when INOUT7 = 0 is satisfied, where the edge detection quantity is set to a positive value (FL238 = 0) and is greater than a threshold (INOUT6-0), it is discriminated as an internal edge. In addition, in the case where the edge detection quantity is set to a positive value (FL238 = 1) and is smaller than the threshold (INOUT6-0), or alternatively, where the edge detection quantity is set to a negative value (FL238 = 1), it is discriminated as an external edge. On the other hand, when INOUT7 = 1 is satisfied, where the edge detection quantity is set to a positive value (FL238 = 0), or alternatively, where the edge detection quantity is set to a negative value (FL238 = 1) and is smaller than the threshold (INOUT6-0), it is discriminated as an internal edge. In addition, in the case where the edge detection quantity is set to a negative value (FL238 = 1) and is greater than the threshold (INOUT6-0), it is discriminated as an external edge. Where the external / internal edge discriminating section 49 discriminates a target to be an internal edge, the halftone dot internal character region detection internal edge signal (\_INEDG) is set to "L" active. The threshold (INOUT6-0) and edge detection quantity (FL237-230) indicates an absolute value.

[0040] Turning to FIG. 2 again, the halftone dot / color

region signal generating section 32 generates a color region signal (\_COL\_DOT) and a halftone dot region signal (\_AMI) based on the color signal (COLOR) and halftone dot discrimination isolation point signal (WAMI, KAMI). That is, the halftone dot / color region signal generating section 32 discriminates whether it is halftone dot region or a color region. In the case that the halftone dot / color region signal generating section 32 activates both a color region signal (\_COL\_DOT) and a halftone dot region signal (\_AMI) to a pixel, it is discriminated that the pixel belongs to color halftone dot region in the region discriminating section 20. This halftone dot /color region signal generating section 32 includes: a black isolation point counting section 60; a white isolation point counting section 61; a color pixel counting section 62; an adder 63; four comparators 64 to 67; an OR circuit 68; a halftone dot region extension processing section 69; and a color region extension processing section 70, as shown in FIG. 12.

**[0041]** The black isolation point counting section 60 counts the number of black isolation points that exist in a 9 x 45 pixel matrix region. Similarly, the white isolation point counting section 61 counts the number of white isolation points that exist in a 9 x 45 pixel matrix region. Outputs from the black isolation point counting section 60 are inputted to terminal A of the adder 63 and terminal P of the comparator 65, respectively. On the other hand, outputs from the white isolation point counting section 61

are inputted to terminal B of the adder 63 and terminal P of the comparator 66, respectively. In addition, an output from the adder 63 is inputted to terminal P of the comparator 64. Reference values (CNTREF17-10, 27-20, and 37-30) are inputted to terminals P of comparators 64 to 66. In addition, outputs from the comparators 64 to 66 are inputted to an OR circuit 68.

**[0042]** In an OR circuit 68, if there is met at least one of the conditions wherein a total number of black and white isolation points is greater than the reference value (CNTREF17-10); the number of black isolation points is greater than the reference value (CNTREF27-20); and the number of white isolation points is greater than the reference value (CNTREF37-30), it is discriminated that the target pixel belongs to a halftone dot region. Then, the halftone dot region signal (\_AMI) is set to "L" active. Then, region expansion processing caused by a halftone dot region extension processing section 69 is applied to the halftone dot region signal (\_AMI).

**[0043]** In the halftone dot region extension processing section 69, as shown in FIG. 13, if any of the pixels (AMI1 to AMI9) corresponding to a position distant by 16 halftone dots in the main scanning direction and by four lines in the sub-scanning direction relevant to the target pixel (AMI5), AMI5 is defined as a halftone dot point irrespective of whether or not AMI5 is a halftone dot, thereby carrying out extension processing of the halftone dot region.

Specifically extension processing is carried out in accordance with the formula below:

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!AMI = !AMI1#!AMI2#!AMI3#!AMI4  
      #!AMI5#!AMI6#!AMI7#!AMI8#!AMI9
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wherein "!" denotes inversion processing, and "#" denotes OR processing, respectively.

**[0044]** A halftone dot region is thus extended at the halftone dot region extension processing section 69, whereby a situation such as below can be avoided: isolation points existing in a 9 x 45 pixel matrix decreases around a boundary of a halftone dot region and a solid color region, and a count value of the isolation points approximates to a reference value. Since the situation such as the above can be avoided, the halftone dot /color region signal generating section 32 can discriminate a halftone dot region more precisely.

**[0045]** In addition, the color pixel counting section 62 counts the number of color pixels that exist in a 9 x 45 pixel matrix region. An output from the color pixel counting section 62 is inputted to terminal P of the comparator 67. A reference value (CNTREF47-40) is inputted to terminal Q of the comparator 67. In this manner, in the case where the number of color pixels is greater than the reference value (CNTREF47-40), the comparator 67 discriminates that the target pixel is a color pixel, and a color region signal (\_COL\_DOT) is set to "L" active. Then, region extension processing caused by a color region extension processing

section 70 is applied to the color region signal (\_COL\_DOT).

[0046] The region extension processing at the color region extension processing section 70 is carried out in the same manner as that at a halftone dot region extension processing section 69. That is, if any one of the pixels that are sixteen-line away from a main scanning direction and four-line away from a sub-scanning direction with reference to the target pixel is a color pixel, the target pixel is regarded as a color pixel regardless of color of the target pixel, and a color region extension processing is carried out.

[0047] Since the color region extension processing section 70 thus extends a color region, the color region can be discriminated as so precisely even though color pixels existing in a 9 x 45 pixel matrix around a boundary of a color region and a black character region decreases and a count number of the color pixels approximates to a reference value, a color region can be discriminated as so precisely.

[0048] Since a halftone dot region signal (\_AMI) and a color region signal (\_COL\_DOT) are generated by the halftone dot /color region signal generating section 32 precisely, the region discriminating section 20 can discriminate a color halftone dot region precisely.

[0049] Turning to FIG. 2, the halftone dot internal character region signal generating section 33 generates a halftone dot internal character region signal (\_MOJI) based on the halftone dot discrimination isolation signals (WAKI,

KAMI), a halftone dot internal character region detection edge signal (\_EDGL), and a dot internal character region detection internal edge signal (\_INEDG). That is, the halftone dot internal character region signal generating section 33 discriminates a halftone dot internal character region from other types of character regions. This halftone dot internal character region signal generating section 33 includes: an OR circuit 75; two AND circuits 78 and 82; an isolation point counting section 76; an internal edge counting section 79; two comparators 77 and 88; and a continuity detecting section 81, as shown in FIG. 14.

**[0050]** The isolation point counting section 76 counts the number of isolation points that exist in an 11 x 11 pixel matrix region. A signal from the OR circuit 75, i.e., a signal indicative of whether or not an isolation point exists relevant to each pixel, is inputted to the isolation point counting section 76. This signal is held by an 11 x 11 pixel matrix whose center is the target pixel, and the pixels corresponding to the isolation point are counted. In addition, the internal edge counting section 79 counts the number of internal edge pixels that exists in a 3 x 3 pixel matrix region. A signal from the AND circuit 78, i.e., a signal indicative of whether or not a pixel belongs to an internal edge region that is a part of an edge region, is inputted to the internal edge counting section 79 with respect to each pixel. This signal is held by a 3 x 3 pixel matrix whose center is the target pixel, and the pixels

belonging to the internal edge region that is a part of edge region are counted. Further, the continuity detecting section 81 detects the continuity of the internal edge, namely, whether or not the pixels belonging to the internal edge region continuously exist.

[0051] The halftone dot discrimination isolation point signals (WAMI, KAMI) are input to the OR circuit 75. Thus, the OR circuit 75 computes a logical sum between WAMI and KAMI. The computation result is inputted to the isolation point counting section 76. Further, an output from the isolation point counting section 76 is inputted to terminal P of the comparator 77. On the other hand, a reference value (CNTREF57-50) is inputted to terminal Q of the comparator 77.

[0052] In addition, a halftone dot internal character region detection edge signal (\_EDGL) and a halftone dot internal character region detection internal edge signal (\_INEDG) are inputted to the AND circuit 78. The AND circuit 78 computes a logical product between \_EDGL and \_INEDG. Then, the computation result is inputted to the internal edge counting section 79. Further, an output from the internal edge counting section 79 is inputted to terminal P of the comparator 80. On the other hand, a reference value (CNTREF67-60) is inputted to terminal Q of the comparator 80.

[0053] An output from the comparator 80 is inputted to the continuity detecting section 81. At this continuity

detecting section 81, with respect to matrix data 83 of 5 x 5 pixel size in which a target pixel a33 is positioned at its center, it is detected whether or not three continuous pixels whose logic is the same as that of the target pixel a33 exist in any of the shown eight directions, whereby the continuity of the internal edges is detected. Specifically, the continuity of the internal edges is detected in accordance with the formula below.

```
!Y = (a11 x a22 x a33) + (a13 x a23 x a33)  
+ (a15 x a24 x a33) + (a35 x a34 x a33)  
+ (a55 x a44 x a33) + (a53 x a43 x a33)  
+ (a51 x a42 x a33) + (a31 x a32 x a33)
```

where "!" denotes inversion processing, "x" denotes AND processing, and "+" denotes OR processing, respectively.

**[0054]** In this way, at the continuity detecting section 81, the continuity of the internal edges is detected, and the detection result is taken into consideration, thereby making it possible to prevent image noise or the like from being incorrectly discriminated as a character region in a halftone dot. That is, the character region in the halftone dot can be discriminated more precisely.

**[0055]** Finally, an output from the comparator 77 and an output from the continuity detecting section 81 are inputted to the AND circuit 82, and an output from the AND circuit 82 is obtained as an output of the halftone dot internal character region signal generating section 33. With such a construction, at the halftone dot internal character region

signal generating section 33, in the case where it is judged that the count value of isolation points is smaller than a reference value (CNTREF57-50), the count value of internal edges is greater than a reference value (CNTREF67-60), and further, the internal edges are continuous, the target pixel is judged as belonging to the halftone dot internal character region. At the halftone dot internal character region signal generating section 33, in the case where it is judged that the target pixel belongs to the halftone dot internal character region, the halftone dot internal character region signal (\_MOJI) is set to "L" active.

[0056] Turning to FIG. 2 again, the MTF control signal generating section 34 generates an MTF control signal (CMPX2-1, KMPX2-0) that controls an operation of the MTF control section 21 based on a color region signal (\_COL\_DOT), a halftone dot region signal (\_AMI), a halftone dot internal character region signal (\_MOJI), and a halftone dot internal character region detection internal edge signal (\_INEDG), character edge region signal(\_EDG) , and black region signal (\_BLACK) . This MTF control signal generating section 34 is composed of a lookup table so as to generate an MTF control signal (CMPX, KMPX) while six region discrimination attribute signals (\_COL\_DOT, \_AMI, \_MOJI, \_INEDG, \_EDG, \_BLACK) are defined as input addresses.

[0057] FIG. 15 shows a part of a table that configures the MTF control signal generating section 34. The MTF control signal (CMPX1-0, KMPX1-0) is a signal that indicates

the content of base processing executed at the MFT correcting section 34. In addition, an MTF control signal (CMPX2, KMPX2) is a signal that indicates whether or not edge enhancement processing is carried out at the MTF correcting section 21. The MTF control signal (CMPX) is a signal for CMY, and the MTF control signal (KMPX) is a signal for K. At the MTF correcting section 21, in the case where the MTF control signal (CMPX1-0, KMPX1-0) is 0, smoothing processing is executed; in the case where the signal is 1, min processing (minimization processing) is executed; and in the case where the signal is 2, no processing is carried out (hereinafter, referred to as "through processing"). In addition, in the case where the MTF control signal (CMPX2, KMPX2) is 0, edge enhancement processing is executed, and in the case where the signal is 1, edge enhancement processing is not executed.

**[0058]** Turning to FIG. 1, the MTF correcting section 21 corrects image sharpness or the like. This MTF correcting section 21 comprises: a cyan (C) correcting section 90 corresponding to each color of CMYK; a magenta (M) correcting section 91; a yellow (Y) correcting section 92; and a black (K) correcting section 93 as shown in Fig. 16 so as to carry out correction processing for four colors at the same time. The CMY correction processing is controlled by an MTF control signal (CMPX2-0) generated at the region discriminating section 20, and K correction processing is controlled by the MTF control signal (KMPX2-0).

**[0059]** Now, a construction of each of the color correcting

sections will be described in more detail. There are provided with the cyan (C) correcting section 90, magenta (M) correcting section 91, yellow (Y) correcting section 92, and black (K) correcting section 93, each of which has the same construction. Therefore, a construction of the cyan (C) correcting section 90 is described here, and descriptions of the other correcting sections are omitted here. This cyan (C) correcting section 90 includes: a matrix generating section 100; a character processing filter section 101 having a variety of filters; two selectors 102 and 103; and an adder 104, as shown in FIG. 16.

**[0060]** The matrix generating section 100 generates 5 x 5 pixel matrix data, and supplies the data to the character processing filter section 101. The character processing filter section 101 is composed of: an edge enhancement quantity generating filter section 110; a smoothing filter section 111; a min filter section 112. With such a construction, the character processing filter section 101 outputs edge enhancement quantity data, smoothing processing data, and min processing data.

**[0061]** The edge enhancement quantity generating filter section 110 includes: a -45 degree differential filter section 120; a 0 degree differential filter section 121; a 45 degree differential filter section 122; a 90 degree differential filter section 123; and a selector 124 that selects a maximum value of the data filtered by these filter sections. In the present embodiment, the -45 degree

differential filter section 120 comprises a filter shown in FIG. 17; the 0 degree differential filter section 121 comprises a filter shown in FIG. 18; the 45 degree differential filter 122 comprises a filter shown in FIG. 19; and the 90 degree differential filter section 123 comprises a filter shown in FIG. 20.

**[0062]** In addition, the smoothing filter section 111 comprises a filter shown in FIG. 21 so that smoothing processing is executed. Further, at the min filter section 112, as shown in FIG. 22, processing is executed such that a minimum value of the 5 x 5 pixel matrix data is defined as target pixel data.

**[0063]** An output from the edge enhancement quantity generating filter section 110 is inputted to terminal A of the selector 102. "00" is inputted to terminal B of the selector 102, and an MTF control signal (CMPX2) is inputted to terminal S. In this manner, at the selector 102, either of the values inputted to terminals A and B is selected and outputted depending on the contents of MTF control signal (CMP2). That is, when the MTF control signal (CMPX2) = 0, edge enhancement processing is executed, and thus, the value inputted to terminal A is selected and outputted at the selector 102. On the other hand, when the MTF control signal (CMPX2) = 1, edge enhancement processing is not executed, and thus, the value inputted to terminal B is selected and outputted at the selector 102.

**[0064]** In addition, an output from the smoothing filter

section 111 is inputted to terminal A of the selector 103, and an output from the min filter section 112 is inputted to terminal B of the selector 103. Further, outputs from the matrix generating section 100, i.e., data obtained when no processing is done by the character processing filter section 101 are inputted to terminals C and D of the selector 103. Furthermore, an MTF control signal (CMPX1-0) is inputted to terminal S of the selector 103. At the selector 103, any of the values inputted to terminals A to D is selected and outputted in accordance with the contents of the MTF control signal (CMPX1-0).

**[0065]** That is, when the MTF control signal (CMPX1-0) = 0, smoothing processing is required. Thus, at the selector 103, the value inputted to terminal A is selected and outputted. In addition, when the MTF control signal (CMPX1-0) = 1, min processing is carried out. Thus, at the selector 103, the value inputted to terminal A is selected and outputted. Further, when the MTF control signal (CMPX1-0) = 2, through processing is carried out. Thus, at the selector 103, the value inputted to terminal C (or D) is selected and outputted.

**[0066]** An output from the selector 102 and an output from the selector 103 are inputted to terminals A and B of the adder 104 respectively. In this manner, at the adder 104, edge enhancement data ("00" if no edge enhancement is carried out) and processing data selected by the selector 103 are added, and the added data is obtained as an output (C7-0)

from the MTF correcting section 21. Processing for the recording density signals (M, Y, K) of the other colors as well is executed in the same manner as for cyan(C).

[0067] In this way, image data (C7-0, M7-0, Y7-0, K7-0) of each color in which processing is applied in the MTF correcting section 21 is transmitted to an image output device such as printer via a printer interface (I/F) 22. Hence, reproduction image is obtained in the image output device.

[0068] Now, an operation of the entire color image processing apparatus having the above described construction will be briefly described here. First, document image information is read by the CCD sensor 11. The analog image data read by the CCD sensor 11 is converted into digital image data. Then, shading correction, interline correction, color aberration correction, magnification change / movement processing, color conversion processing, color correction, region discrimination processing, and MTF correction are applied sequentially to the digital image data. Then, based on the image data to which a variety of image processing is applied, the document reproduction image is outputted on a recording medium by a printer or the like via the printer interface (I/F) 22.

[0069] The region discriminating section 20 discriminates where the target pixel belongs to among from a color region, a monochrome region, a halftone dot region,

a character region, and a halftone dot internal character region. With respect to the halftone dot region, character region, and halftone dot internal character region, it is discriminated whether or not these regions are based on color or monochrome. Discrimination of the color halftone dot region is carried out based on a discrimination result obtained by the halftone dot / color region signal generating section 32. That is, it depends on whether or not it is a halftone dot region and whether or not it is a color region. Firstly, a method of halftone dot region discrimination will be described in the next paragraph.

**[0070]** For discriminating halftone dot region, firstly, the black isolation point counting section 60 and the white isolation point counting section 61 count the number of black isolation points and that of white isolation points existing in a 9 x 45 pixel matrix, respectively, which is based on halftone dot discrimination isolation point signals (WAMI and KAMI) generated by the various edge signal generating section 31. Next, the adder 63 obtains a sum of a count value of the black isolation points and that of the white isolation points. Then, the comparators 64 through 66 compare the sum of the black isolation points and the white isolation points, the count value of the black isolation points, and that of the white isolation points with their respective reference values (CNTREF17-10, 27-20, 37-30). Comparison results obtained by the comparators 64 through 66 are inputted to the OR circuit 68.

[0071] At least one of the following three conditions is met at the OR circuit 68, it is discriminated that the target pixel belongs to a halftone dot region. The conditions to be met are: (1) the sum of the black isolation points and the white isolation points is larger than the reference value (CNTREF17-10); (2) the count value of the black isolation points is larger than the reference value (CNTREF27-20); and (3) the count value of the white isolation points is larger than the reference value (CNTREF37-30). When at least one of the above conditions is met, a halftone dot region signal (\_AMI) is set to "L" active. After that, the halftone dot region extension processing section 69 applies a region extension processing to the halftone dot region signal (\_AMI).

[0072] Next, a method of color region discrimination will be described. Firstly, the color pixel counting section 62 counts the number of color pixels existing in a 9 x 45 pixel matrix, which is based on a color signal (COLOR) generated by the various edge signal generating section 31. Next, the comparator 67 compares the count value of the color pixels with a reference value (CNTREF 47-40). If the count value is larger than the reference value (CNTREF 47-40), it is discriminated that the target pixel belongs to a color region. Subsequently, a color region signal (\_COL\_DOT) is set to "L" active. After that, the color region extension processing section applies a region extension processing to the color region signal (\_COL\_DOT).

[0073] In case a halftone dot region signal (\_AMI) and a color region signal (\_COL\_DOT) are set active in accordance with a halftone-dot-region discrimination and color-region discrimination result obtained by the halftone dot / color region signal generating section 32, the region discriminating section 20 discriminates that the target pixel belongs to a color halftone dot region. Since region extension processing is applied to the halftone dot region signal (\_AMI) and the color region signal (\_COL\_DOT), halftone dot region discrimination and color region discriminations are carried out more precisely. Accordingly, the region discriminating section 20 can discriminate a color halftone dot region precisely.

[0074] Next, a method of discriminating a halftone dot internal character region will be described. The halftone dot internal character region is discriminated at the halftone dot internal character region signal generating section 33 provided at the region discriminating section 20. The OR circuit 75 computes a logical sum of the halftone dot discrimination isolation point signal (WAMI, KAMI) generated by the various-edge signal generating section 31. Then, the logical sum computed by the OR circuit 75 is inputted to the isolation point counting section 76. Then, the isolation point counting section 76 counts the number of white and black isolation points that exist in an 11 x 11 pixel matrix region. Then, the comparator 77 compares the isolation point count value with the reference value

(CNTREF57-50). The comparison result is inputted to the AND circuit 82.

**[0075]** On the other hand, in parallel to the above processing, the AND circuit 78 computes a logical sum between the halftone dot internal character region detection internal edge signal (\_EDGL) and halftone dot internal character region detection edge signal (\_INEDG) generated by the various-edge signal generating section 31. Then, the logical product computed by the AND circuit 78 is inputted to the internal edge counting section 79. Then, the internal edge counting section 79 counts the number of internal edges that exist in a 3 x 3 pixel matrix region. Then, the comparator 80 compares the internal edge count value with the reference value (CNTREF67-60). The comparison result is inputted to the continuity detecting section 81. Then, the continuity detecting section 81 detects the continuity of the internal edges. Then, data concerning the count value of the internal edges and the presence or absence of continuity is inputted to the AND circuit 82.

**[0076]** Finally, at the AND circuit 82, in the case where the isolation point count value (WAMI + KAMI) is smaller than the reference value (CNTREF57-50), and moreover, the internal edge count value (\_EDGL x \_INEDG) is greater than the reference value (CNTREF67-60) and the internal edges are continuous, the target pixel is judged as belonging to the halftone dot internal character region. Then, the halftone dot internal character region signal (\_MOJI) is

set to "L" active. The halftone dot internal character region is discriminated for all the pixels of the input image data by repeatedly moving the target pixels in the main scanning direction one by one and moving them by one pixel in the subsidiary scanning direction when the pixel reaches a final position in the main scanning direction.

**[0077]** Now, discrimination processing at the halftone dot internal character region signal generating section 33 will be described by way of showing a specific example shown in FIG. 23. Here, a description will be given by exemplifying discrimination processing in part of an image (region R in (A) of FIG. 23 (refer to (B) of FIG. 23) on which uppercase letter H is drawn in the halftone dot as shown in (A) of FIG. 23.

**[0078]** First, in region R1 shown in (B) of FIG. 23, as shown in (C) of FIG. 23, isolation points exist all over the region, and no internal edge exist. Thus, at the halftone dot internal character region signal generating section 33, the comparator 77 judges that the isolation point count value (WAMI + KAMI) is greater than the reference value (CNTREF57-50). In addition, the comparator 80 judges that the internal edge count value (\_EDGL x \_INEDG) is smaller than the reference value (CNTREF67-60). Further, the continuity detecting section 81 judges that the internal edge is not continuous. Therefore, the halftone dot internal character region signal (\_MOJI) is set to "H" by the AND circuit 82. That is, it is discriminated that the

target pixel shown in (C) of FIG. 23 fails to belong to the halftone dot internal character region.

**[0079]** On the other hand, in region R2 shown in (B) of FIG. 23, as shown in (D) of FIG. 23, isolation points exist in half or less of the region, and the internal edges continuous at the center of the region exist. Thus, in the halftone dot internal character region signal generating section 33, the comparator 77 first judges that the isolation point count value (WAMI + KAMI) is smaller than the reference value (CNTREF57-50). In addition, the comparator 80 judges that the internal edge count value (\_EDGL x INEDG) is greater than the reference value (CNTREF67-60). Further, the continuity detecting section 81 judges that the internal edges are continuous. Therefore, the halftone dot internal character region signal (\_MOJI) is set to "L" by the AND circuit 82. That is, the target pixel shown in (D) of FIG. 23 is discriminated as belonging to the halftone dot internal character region.

**[0080]** As has been described above, the halftone dot internal character region can be discriminated because the halftone dot region and halftone dot internal character region are different from each other in their characteristics. That is, the halftone dot region is characterized in that a large number of isolation points exist, a small number of internal edges exist, and the internal edges are not continuous. On the other hand, the halftone dot internal character region is characterized in that a small number

of isolation points exist, a large number of edges exist, and the internal edges are continuous. Thus, the halftone dot region and halftone dot internal character region are completely reversed in their characteristics. Therefore, the halftone dot internal character region can be precisely discriminated by making best use of a difference in characteristics of these regions each.

**[0081]** As a result of region discrimination carried out at the region discriminating section 20, i.e., in accordance with a variety of region attribute discrimination signals, the MTF correcting section 21 applies image processing according to a variety of attributes. Specifically, smoothing processing is applied to the halftone dot region, and edge enhancement processing is applied to the character region. Thus, when a character exists on a halftone dot image, smoothing processing is applied to the halftone dot region excluding the character region, and edge enhancement processing is applied to the halftone dot internal character region. However, it should be noted that smoothing processing is applied to an entirety of the black halftone dot region regardless of presence / absence of a character.

**[0082]** Smoothing processing is applied to an entirety of the black halftone dot region because of the following reason. As shown in FIG. 24A, if a group of black halftone dots is erroneously discriminated as a black character, proportion difference between black(K) and cyan(C), magenta(M), yellow(Y) becomes larger. Thereby, hue of a

reproduction image is different from that of an original image and the reproduction image is likely to have image noises. Therefore, smoothing processing is applied to an entirety of the black halftone dot region without character region discrimination in a black halftone dot region so as to avoid image noises. On the other hand, as shown in FIG. 24B, even if a group of color halftone dots is erroneously discriminated as a color character, proportion difference between black(K) and cyan(C), magenta(M), yellow(Y) does not change. Therefore, hue of a reproduction image does not differ compared with that of an original image. From this reason, smoothing processing is not necessary for an entirety of the color halftone dot region, different from case of a black halftone dot region.

**[0083]** However, as shown in FIG. 25, in case a black character exists in a color halftone dot region and a color region is not extended, halftone dots around boundary of a character region discriminated as black halftone dots. That is, the color region cannot be discriminated as so precisely. Once the color halftone dots around the boundary of the character region is discriminated as black halftone dots, smoothing processing is applied to the character region. As a result, the character is blurred. Therefore, a color image processing apparatus of the present invention has the color region extending section 70 to extend a color region. Thereby, color halftone dots around boundary of a black character region is surely discriminated as so and edge

enhancement processing is surely applied to the black character in the color halftone dot region. Accordingly, a character in a color halftone dot region can be reproduced precisely without getting blurred.

**[0084]** As described in the above, the color image processing apparatus directed to this embodiment has the color region extending section 70 to extend a color region. Thereby, even if color pixels existing in a 9 x 45 pixel matrix region decreases around a boundary of a color halftone dot region and a black character region and a count value of the color pixel approximates a reference value, the color region can be discriminated as so precisely. Even if a black character exists in a color halftone dot region, the halftone dot / color region signal generating section 32 can discriminate the color region precisely. Accordingly, the color halftone dot region can be discriminated as so precisely. Furthermore, the halftone dot internal character region signal generating section 33 discriminates a halftone dot internal character region precisely. Therefore, edge enhancement processing can surely be applied to the character region in the color halftone dot region. As a result, the character in the color halftone dot region is reproduced with high quality.

**[0085]** The above described embodiment is provided for mere illustrative purpose, and the present invention is not limited thereto. Of course, various modifications or variations can occur without departing the spirit of the

invention. For example, in the above described embodiment, although an isolation point is detected as a halftone dot characteristic, any other point may be detected as far as such point characterizes a halftone dot without being limited thereto. In addition, the present invention is applicable to an image processing apparatus such as digital copying machine, printer, and facsimile machine other than above described embodiment. Further, specific numeral values shown in the above-described embodiment (for example, matrix size or the like) are provided for mere illustrative purposes.